

These diagrams are shown in order to indicate the possibilities of the instrument. It is proposed to make a series of tests on the various kinds of metals used in the industries particularly with the object of investigating the region immediately beyond the elastic limit and the effect of suddenly applied loads and loads applied very gradually. The characteristic of the method of applying the load in all the diagrams shown is that the rate at which the extension of the specimen increases is approximately constant, because the pressure is applied to the straining cylinder of the testing machine by a ram driven in at a nearly constant rate. The rate at which the load is applied is therefore variable, as will be understood from fig. 8. The scale of the extension can in the particular instrument described be magnified conveniently about eight times, so that it is only suitable for investigations outside the true elastic region. The author hopes to communicate a paper shortly giving the description of a similar instrument for obtaining automatic diagrams within the elastic region.

### *The Passage of Homogeneous Röntgen Rays through Gases.*

By E. A. OWEN, B.Sc., 1851 Exhibition Scholar of the University College of North Wales, Trinity College, Cambridge.

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#### *Introduction.*

The phenomena attending the passage of Röntgen rays through gases has been examined by several experimenters. The relative ionisation produced in different gases was investigated early in the history of Röntgen rays by Perrin\* and Rutherford,† and later by Sir J. J. Thomson,‡ Strutt,§ McClung,|| Eve,¶ Barkla,\*\* and Crowther.†† Some of these experimenters

\* Perrin, 'Ann. de Chimie et de Phys.,' 1897, vol. 11, p. 496.

† Rutherford, 'Phil. Mag.,' 1897, vol. 43, p. 241.

‡ J. J. Thomson, 'Camb. Phil. Soc. Proc.,' 1900, vol. 10, p. 10.

§ Strutt, 'Roy. Soc. Proc.,' 1903, vol. 72, p. 209.

|| McClung, 'Phil. Mag.,' 1904, vol. 8, p. 357.

¶ Eve, 'Phil. Mag.,' 1904, vol. 8, p. 610.

\*\* Barkla, 'Camb. Phil. Soc. Proc.,' 1909, vol. 15, p. 257; 'Phil. Mag.,' 1910, vol. 20, p. 370.

†† Crowther, 'Roy. Soc. Proc.,' 1908, vol. 82, p. 103.

allowed the rays to strike the electrodes and the walls of the ionisation chambers; this gave rise to corpuscular radiation which was totally absorbed in the gas, so that the ionisation observed was higher than the true value, and consequently the apparent relative ionisation was smaller than it should be for those gases in which the ionisation is greater than in air. Sir J. J. Thomson, McClung, and Crowther took precautions against this source of error, but in every case rays direct from a Röntgen bulb were used, and these rays were necessarily heterogeneous, and the heterogeneity was different in the various bulbs. In experiments on the relative ionisation in gases by Röntgen rays, not only rays of exactly the same hardness and the same intensity should be used to ionise each gas, but in order to obtain quite definite results it is necessary to use rays of quite a distinct hardness. Barkla's discovery of homogeneous rays emitted by different metals when Röntgen rays fall upon them makes it possible to use rays of a definite hardness. Such homogeneous rays have been used by Barkla to investigate the amount of ionisation relative to air produced in different gases and vapours.

The main object of the following research is to investigate more fully the various phenomena observed when homogeneous rays pass through gases composed of elements in the group in which no appreciable homogeneous radiation has been detected for rays of penetrating power within the range of that of those homogeneous beams emitted by metals of atomic weight from iron to silver. The gases used are air, carbon dioxide, and sulphur dioxide. The investigation may be divided into three parts—

- (1) The absorption of homogeneous rays.
- (2) The variation of ionisation with pressure.
- (3) The ionisation, relative to air, produced in a gas by rays of different hardnesses.

#### *Apparatus.*

In the present work we deal with narrow pencils of homogeneous Röntgen rays. It was found very difficult to obtain a sufficiently intense pencil by placing a piece of metal in the path of the rays from an ordinary type of bulb; in this case only a small solid angle of rays emanating from the anticathode could be utilised to produce a secondary homogeneous beam, and in addition the rays had to traverse the glass wall of the tube and a certain column of air before they fell on the radiator, so that their intensity was greatly diminished. The problem therefore is to construct a bulb which will allow the primary rays to strike the radiator immediately after they leave the anticathode, and consequently reduce the size of the radiator,

which would still envelop a greater solid angle of rays than would be the case in an ordinary bulb with a much larger radiator. The following is an account of an attempt made to construct such a bulb which could be used with the same ease as an ordinary type of bulb:—

The bulb is designed to have the anticathode on the surface. Since it is to be permanent and capable of being run for any reasonable length of time it is essential that no wax joints be used in its construction. A glass-metal air-tight joint had therefore to be used. The joint adopted was that used by Roebuck\* in experiments on "The Bursting Strength of Glass Tubing." The principle of the method is as follows:—A thick glass tube, diameter about 2.5 cm., is taken and the outside carefully cleaned. A coating of platinum is spluttered over this tube for about 5 cm. of its length. This is done by brushing over the glass with a water solution of platinum chloride and dextrin containing 1 to 2 per cent. of each; the tube is then gently heated until the solution dries up, and afterwards it is incinerated in a Bunsen flame. After this process a thin conducting semi-transparent film of platinum is left on the glass. To secure a perfectly continuous layer all over the surface, two or three coatings of platinum are added in a similar way. It is essential to get a continuous layer of platinum on the glass tube, and to get it the glass surface must be very clean; distilled water should also be used to make up the solution of platinum chloride and dextrin. The next step is to deposit electrolytically a thick layer of copper on the platinum. The deposit should be very fine, so as to obtain a smooth surface on the copper. A very small current is therefore sent through the voltameter. A layer of copper, about 1 mm. thick, is deposited in this way. The glass tube is now ready to be soldered on to any metal tube which fits over it. Preliminary experiments on this method showed that the joint was quite air-tight, even when the metal tube was simply soldered round its edge to the copper layer on the glass.

A large distilling flask, about 20 cm. in diameter, is taken and a wide piece of thick glass tubing, about 8 cm. in length, fused to it diametrically opposite to its neck and in line with it. Over about 5 cm. of this tube is deposited a thick layer of copper by the above described process. A brass cap B (fig. 1*a*) is now put over the end of the tube, the brass tube T fitting over the copper deposit. The edge of the tube T is carefully soldered on to the deposit on the glass. The other part of the cap B is a thick circular brass disc having a circular hole, 1 cm. in diameter, bored at its centre, and which is soldered to the other end of the tube T. Over this hole is soldered a piece of silver foil, thick enough to stop all cathode particles travelling

\* Roebuck, 'Phys. Review,' 1909, vol. 28, p. 264.

with a velocity corresponding to an equivalent spark gap of 4 to 5 cm. The collar W allows cold water to circulate round the tube, thus keeping the joint cool. This glass-metal joint proved very satisfactory; no trouble at all was experienced in obtaining it air-tight.

The cathode is slightly concave, so as to tend to bring the rays to a focus on the silver window. The beam of Röntgen rays emerging from the window can be made very intense, and a very large solid angle of the rays can be utilised to produce secondary beams.

A silver anticathode is used because a beam of Röntgen rays is required which is sufficiently hard to stimulate the homogeneous beams of metals of atomic weight lower than silver. It was also preferred to platinum because the latter occludes hydrogen very rapidly when heated, and would therefore be unsuitable for this purpose. Silver, however, occludes oxygen, but the amount it occludes is inappreciable at the temperature to which the anticathode is raised. Platinum was not actually tried; possibly, with good cooling arrangements, it may be used.

The bulb is fitted with a palladium softener and is permanently connected to a Töpler pump and charcoal tube. The equivalent spark gap can be kept quite constant by manipulating the palladium softener and charcoal tube, or, when liquid air is not available, the Töpler pump. The equivalent spark gap was kept at 4.5 cm. and the coil worked with a Cox mechanical interrupter, which is much more satisfactory than any form of mercury break tried, in that it gives a much steadier discharge.

The bulb was fixed up in a lead box. The radiators were placed over the silver anticathode, as shown in fig. 1, and were held always in the same position by a little aluminium frame, which was rigidly fixed to the lead box. The dimensions of the aperture S in the lead box were 1.5 cm. by 4.7 cm., and the centre of the radiator was about 7 cm. from it. A small lead collar, 0.5 cm. high, was placed 1 cm. from the centre of the window, to stop any rays direct from the bulb from passing through the aperture S. The beams sent out by the radiators were tested for their homogeneity before the rest of the apparatus was set up. This was done in the ordinary way, by putting an electroscope in the path of the rays and finding the percentage absorption produced by successive sheets of aluminium placed in front of it. The required homogeneity was detected.

A standardising ionisation chamber A, with central rod electrode, was placed in the direction of the rays at a distance of about 30 cm. from the aperture S. The inner surface of the chamber, together with the surface of the electrode, was covered with layers of filter paper, and the rays passed into the chamber through a parchment window. The electrode was carefully

insulated from the chamber and was connected through an earthing key to a Wilson tilted electroscope, the needle of the earthing key being connected to a potential divider.

A second ionisation chamber B, which contained the gases under investiga-

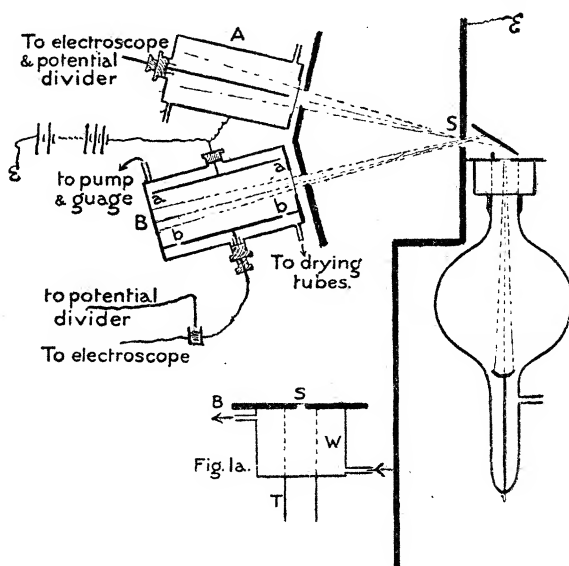


FIG. 1.

tion, was placed parallel to the rays and at the same distance from the aperture *S* as the standardising chamber *A*. This chamber was 25 cm. long and contained two parallel aluminium electrodes at a distance of about  $4\frac{1}{2}$  cm. apart. One of these, *aa*, 24 cm. by 6 cm., was raised to a high potential, and the other, 18 cm. by 6 cm., connected through an earthing key to the potential divider and a second Wilson electroscope. The second of these electrodes was guarded at its ends by two plates of the same width and in the same plane as the electrode, and each 3 cm. long; the gap between the plates and the electrode was about 3 mm. wide. The plates were soldered to the ends of the chamber, which was earthed. The guard ring served to sweep away all the ions produced by the corpuscular radiation emitted from the ends of the chamber when the rays strike it, and the ions produced in the gas by the Röntgen rays, before coming to the region between the electrodes, *aa* and *bb*. The electrodes, guard plates, and the surface of the chamber were covered with layers of filter paper. The window through which the rays entered was of parchment, supported by two very thin cross-pieces of aluminium. A lead screen was placed in front of the chamber, having a rectangular aperture in it measuring 1.8 cm. square. A pencil of

rays from the aperture S would then pass between the electrodes without touching them.

Both of the chambers were made air-tight; the chamber B was permanently connected to a Töpler pump and gauge. The same specimen of dried air was kept in the standardising chamber throughout the experiment; the other chamber was filled with the different gases examined, which were carefully dried and purified.

It was found that a potential of about 300 volts was ample to ensure saturation currents in the gases used. The electroscopes were worked at a sensitiveness of about 60 and 30 divisions per volt respectively. The readings could be taken very quickly. A certain fixed deflection was taken in the standardising electroscope in each case, and the corresponding deflection in the other electroscope observed. The rise of the potential of each leaf was immediately determined with the potential divider; in this case the error introduced is only that due to the fluctuation of the zero during the interval this potential was determined. This interval, however, was very short, and the leaves as a rule were very steady.

#### *Absorption Experiments.*

The first set of experiments were carried out to determine the absorption coefficient for different homogeneous beams in the three gases, air, carbon dioxide and sulphur dioxide. A wide brass cylinder, exactly 20 cm. long, with parchment windows at its ends, was placed directly in front of the chamber B and parallel to the rays coming from the radiators. It was made air-tight and connected to a gauge and a mercury pump. A lead screen with a small aperture in it was placed in front of the cylinder, so that only a narrow beam of rays passed through it.

In the case of air and carbon dioxide the absorption of the rays was measured at atmospheric pressure. The determination of the ionisation in B when the cylinder was evacuated, and afterwards when it was filled with the gas, sufficed to find the coefficient of absorption. The first reading gives a measure of the initial intensity  $I_0$ , and the second, the intensity  $I$  after passing through a column of gas 20 cm. long. Hence from the formula  $I = I_0 e^{-20\lambda}$ ,  $\lambda$ , the coefficient of absorption in the gas (at that temperature and pressure) for the particular type of rays used is directly calculated.

With sulphur dioxide at atmospheric pressure it was found that the absorption was very great for the softest rays used—so great that the ionisation produced in the chamber B was almost inappreciable when bulb was run for about one minute. Readings were consequently taken with diminished pressures in the cylinder. Plotting the logarithm of the observed

ionisation in the chamber B against the pressure of the gas in the absorbing chamber, we get straight lines for all the homogeneous beams used. These curves are shown in fig. 2.

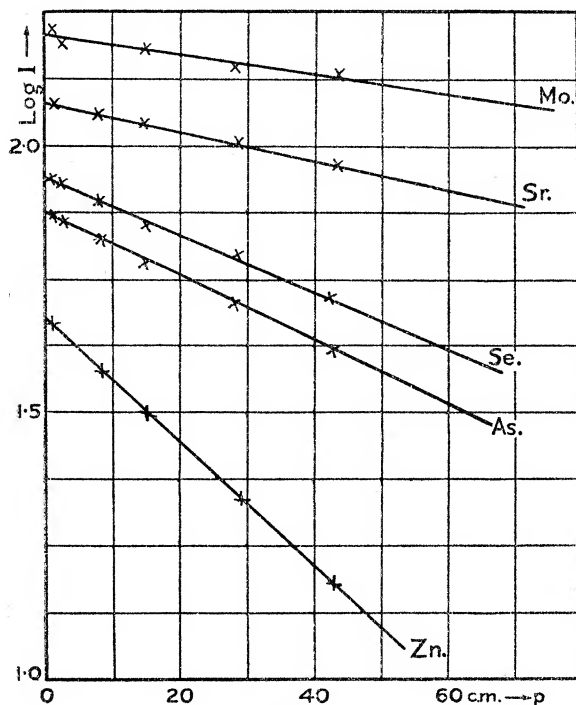


FIG. 2.

Hence the law of absorption for homogeneous beams in a gas becomes

$$I = I_0 e^{-\lambda p x / \pi},$$

when  $p$  is the pressure of the gas, and  $\pi$  the atmospheric pressure. From the curves in fig. 2 the absorption coefficient of the rays at atmospheric pressure can be obtained. The values of the coefficients of absorption, defined in this way, of the respective rays by the different gases at  $0^\circ$  C. and 760 mm. are given in Table I; the mass absorption coefficients are also tabulated for convenience.

Fig. 3 shows the relation existing between the atomic weights of the radiators giving out the homogeneous rays and the mass absorption coefficients of the different rays for any individual gas. The logarithm of the atomic weight of the radiator is plotted against the logarithm of the mass absorption coefficient. For each gas, the points lie on straight lines within the limits of experimental error, and these straight lines are parallel to each other. Hence the absorption coefficients of the different homogeneous

Table I.

Radiator.	Atomic weight of radiator. <i>w.</i>	Air.		CO <sub>2</sub> .		SO <sub>2</sub> .		$\lambda/\rho$ .*		
		$\lambda$ .	$\lambda/\rho$ .	$\lambda$ .	$\lambda/\rho$ .	$\lambda$ .	$\lambda/\rho$ .	C.	Mg.	Al.
Fe .....	55.9	0.0254	19.72	0.0456	23.04	0.2673	91.2	10.1	80	88.5
Ni .....	58.7	0.0186	14.39	0.0319	16.10	0.1691	57.73	6.58	51.8	59.1
Cu .....	63.6	0.0130	10.08	0.0227	11.48	0.1404	47.90	5.22	41.4	47.7
Zn .....	65.7	0.0108	8.41	0.0184	9.29	0.1040	35.49	4.26	34.7	39.4
As .....	75.0	0.00592	4.59	0.00988	4.99	0.0548	18.69	2.49	19.3	22.5
Se .....	79.2	0.00442	3.43	0.00782	3.95	0.0449	15.31	2.04	15.7	18.9
Sr .....	87.6	0.00258	2.00	0.00420	2.12	0.0272	9.29	—	—	—
Mo .....	96.0	0.00166†	1.29	0.00281	1.42	0.0170	5.81	—	—	—

\* Taken from Barkla and Sadler, 'Phil. Mag.,' May, 1909, p. 749.

† Deduced from the curve.

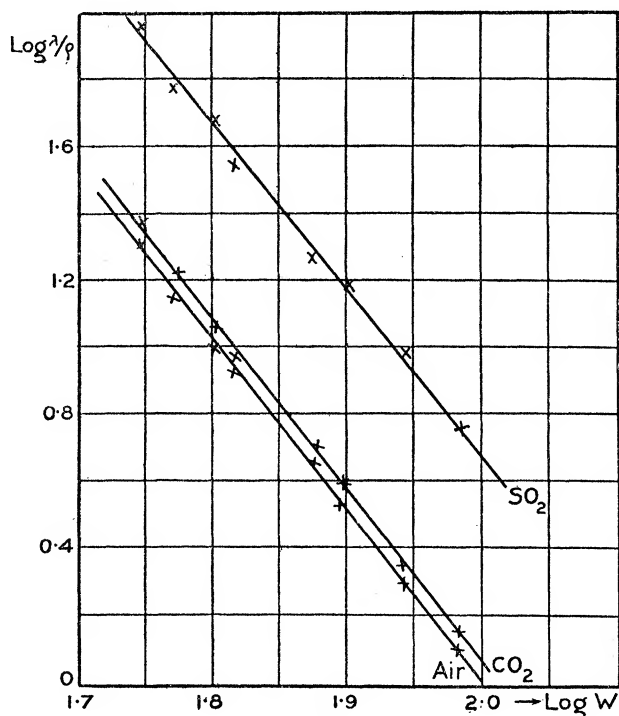


FIG. 3.

radiations in air are proportional to the absorption coefficients of those radiations in carbon dioxide or sulphur dioxide. Barkla and Sadler\* found the same proportionality between the absorption coefficients of primary radiation by two elements, provided the primary radiation was not hard enough to excite the characteristic radiation of those elements.

\* Barkla and Sadler, 'Phil. Mag,' 1909, p. 739.



Hence, generally, if  ${}_X\lambda_A$  denote the coefficient of absorption of a certain radiation X in a substance A, whether elementary or compound (using the notation adopted by Barkla and Sadler),

$$\frac{{}_X\lambda_A}{{}_X\lambda_B} = \frac{{}_Y\lambda_A}{{}_Y\lambda_B} = \frac{{}_Z\lambda_A}{{}_Z\lambda_B},$$

provided the radiations X, Y, Z do not excite the characteristic radiations of the substances A and B. (When A and B are compounds the law does not hold if the rays excite the characteristic radiation of any one of the elements present.)

The straight lines in fig. 3 incline to the axis of abscissa along which  $\log w$  is measured, at an angle  $\tan^{-1}(-5)$  approximately, so that

$$\lambda/\rho = cw^{-5} \text{ (approximately),}$$

where  $c$  is a constant depending upon the nature of the absorbing medium.

Hence the coefficient of absorption of homogeneous Röntgen radiation in **any** of the gases investigated is approximately inversely proportional to the fifth power of the atomic weight of the element emitting the characteristic radiation. It is possible that the absorption of these rays follows the same law universally, whatever the absorbing medium may be. Taking, for example, the values given by Barkla and Sadler for  $\lambda/\rho$  in carbon, magnesium, and aluminium for the different rays, we find that the same law approximately holds also for these elements in the case of rays of penetrating power from iron to strontium radiation. It is desirable, however, that rays of a wider range of penetrating power be used before a general conclusion be arrived at, but, for the range of rays examined in the present work, the above relation undoubtedly approximately holds.

#### *Ionisation and Pressure.*

When a beam of Röntgen radiation passes through a gas it gives rise to both secondary Röntgen radiation and corpuscular radiation. With the pressures used in the experiment the corpuscular rays are totally absorbed, but this is not the case with the secondary Röntgen rays. The amount of secondary radiation produced in these light gases is, however, very small. Barkla finds that the energy of the secondary radiation proceeding from 1 cm. length of primary beam passing through air at atmospheric pressure and about 15° C. is 0.00024 of the energy of the primary radiation passing through. Consequently, the amount of ionisation produced by these secondary rays in the chamber is negligible compared with the whole amount of ionisation produced in the chamber. The only way by which these secondary rays can give rise to an appreciable amount of ionisation is by the production of

corpuscular radiation if the rays were allowed to strike the metal electrodes and walls of the chamber. To avoid this, the electrodes and the walls of the chamber are covered with layers of filter paper. With this arrangement the amount of ionisation produced by the corpuscular radiation from the electrodes and the walls will be negligible, because the amount of corpuscular radiation sent out from the filter paper is of the same order as the corpuscular radiation produced in the gas, and, further, the corpuscular radiation sent out by the walls on account of the secondary rays penetrating the paper will be totally absorbed in the paper, and therefore not allowed to produce any ionisation in the gas.

In each gas there is a correction to be applied to the observed value of the ionisation due to the absorption of the rays in the gas before they reach the central plate electrode, and in the volume of gas under investigation between the electrodes. These corrections were rather small in air and carbon dioxide, but much larger in sulphur dioxide.

Some of the corrected results obtained with air and carbon dioxide are represented graphically in fig. 4. All the curves are straight lines through the origin.

In the case of  $\text{SO}_2$  the method of procedure was somewhat different.

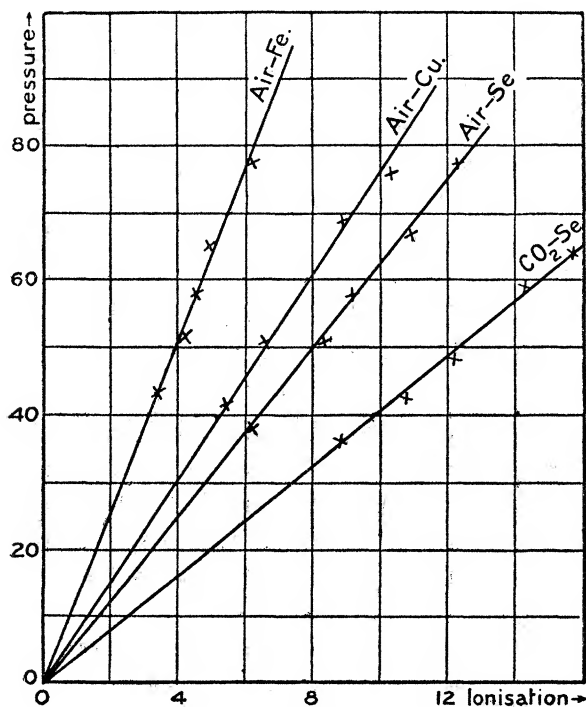


FIG. 4.

On the assumption that the ionisation is proportional to the pressure, it is very easy to calculate what the ionisation should be at any pressure, knowing the dimensions of the electrodes and guard ring and the coefficient of absorption of the rays in the gas.

Suppose  $a$  is the distance from the middle of the first gap to the parchment window, and  $b$  that of the second gap. Let  $I_0$  be the intensity of the rays on the inner side of the parchment window, and let  $p$  be the pressure of the gas in the chamber. If  $\lambda$  is the coefficient of absorption of the rays in the gas at the given temperature and 760 mm. pressure,

The intensity of the radiation at a distance  $x$  from the end  $= I_0 e^{-\lambda x p / \pi}$ ,

Ionisation produced at  $x$  in small layer  $dx$   $= \frac{p}{\pi} A I_0 e^{-\lambda x p / \pi} dx$ ,

where  $A$  is the ionisation produced by rays of unit intensity in travelling through a unit distance in the gas at atmospheric pressure.

$$\begin{aligned} \text{Ionisation produced between the plates} &= \frac{p}{\pi} A I_0 \int_a^b e^{-\lambda x p / \pi} dx \\ &= \frac{A I_0}{\lambda} (e^{-\lambda a p / \pi} - e^{-\lambda b p / \pi}); \end{aligned}$$

$$\text{i.e., say, } y = \frac{A I_0}{\lambda} z, \text{ where } z = e^{-\lambda a p / \pi} - e^{-\lambda b p / \pi}. \quad (1)$$

The quantity  $A I_0 / \lambda$  is a constant for the same gas for any particular type of rays used. All the quantities in the expression  $z$  are accurately determined. With the aid of these the value of  $z$  can be calculated for any pressure. These calculated values of  $z$ , multiplied by a constant, are in very close agreement with the observed values of the ionisation for all the pressures taken. Some of the curves obtained are shown in fig. 5. The agreement which exists between the calculated and observed values justifies the assumption that the ionisation in the gas is proportional to the pressure.

#### *Relative Ionisation.*

The ionisations in carbon dioxide and sulphur dioxide are calculated relative to air as a standard. The chamber B is initially filled with dry air and the ionisation produced in it by each of the homogeneous beams is measured. Dry carbon dioxide is then substituted for the air, and another series of observations taken with the gas at atmospheric pressure. In the case of sulphur dioxide, four sets of readings were taken with the gas at different pressures.

For any one definite type of rays we have by equation (1) for any gas

$$y = \frac{A I_0}{\lambda} z, \text{ and for air } y_a = \frac{A_a I_0}{\lambda_a} z_a.$$

Hence  $A/A_a$ , the ionisation in the gas relative to air for that certain radiation, is equal to

$$y\lambda z_a/y_a\lambda_a z,$$

where  $y$  and  $y_a$  are the observed ionisations in the gas and air respectively,  
 $\lambda$  and  $\lambda_a$ , the coefficients of absorptions of the rays in the gas and air  
 respectively at the given temperature and 760 mm. pressure.  
 $z$  and  $z_a$  are expressions defined by equation (1).

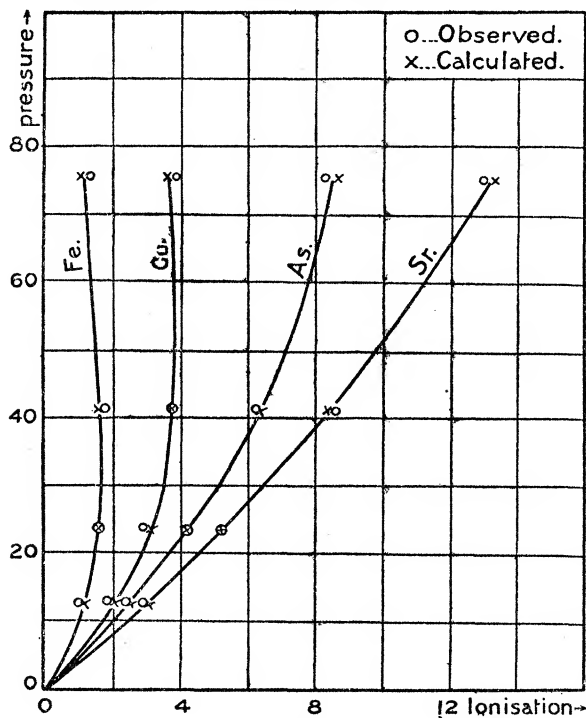


FIG. 5.

The calculated values of the relative ionisation for all the different rays are tabulated in Table II. Within the limits of experimental error, the relative ionisation is constant in the same gas for the range of rays employed.

Knowing the coefficient of absorption of all the rays in the different gases, we can find the relative total ionisation.

For the total ionisation produced in a gas at pressure  $p$

$$= \frac{p}{\pi} A I_0 \int_0^\infty e^{-\lambda' x p / \pi} dx = \frac{A I_0}{\lambda'}.$$

where  $\lambda'$  is calculated from the values of  $\lambda$  given in Table I, allowing for scattering.

Hence  $T$ , the relative total ionisation  $= A \lambda'_a / A_a \lambda'$ .

Table II.

Radiator.	Relative ionisation in		Relative total ionisation in	
	CO <sub>2</sub> .	SO <sub>2</sub> .	CO <sub>2</sub> .	SO <sub>2</sub> .
Fe .....	1·581	11·34	0·90	1·07
Ni .....	1·546	11·57	0·88	1·25
Cu .....	1·552	11·84	0·89	1·08
Zn .....	1·538	11·52	0·91	1·18
As .....	1·510	11·73	0·91	1·22
Se .....	1·533	11·76	0·86	1·11
Sr .....	1·527	11·81	0·94	1·04
Mo .....	1·541	11·45	0·92	1·00

Table II gives the values of  $T$  calculated from this formula. It is observed that for the same gas the relative total ionisation is approximately constant for the range of rays used. There is a very great difference between the values of the relative ionisation in the two gases, but the difference between the relative total ionisation is comparatively small.

It appears, therefore, that for these light gases—the characteristic radiation of whose constituent elements has not been detected—the total number of ions produced by homogeneous beams of equal intensity is approximately the same in each gas for any particular type of rays.

#### *Summary.*

(1) The absorption of the different homogeneous radiations in a light gas, such as CO<sub>2</sub> or SO<sub>2</sub>, is proportional to the absorption of those radiations in air.

(2) The absorption of homogeneous radiation in a gas is proportional to the pressure of that gas.

(3) For the homogeneous rays emitted by metals of atomic weight ranging from that of iron to that of molybdenum, the coefficient of absorption in the gases investigated is approximately inversely proportional to the fifth power of the atomic weight of the radiator which emits that characteristic radiation, *i.e.*  $\lambda \propto w^{-5}$ .

(4) The amount of ionisation produced in a thin layer of a gas is directly proportional to the pressure of the gas.

(5) The ionisation relative to air is approximately constant in the same gas for the different homogeneous rays.

(6) The total number of ions produced by homogeneous beams of equal

intensity is approximately the same in each gas for any particular type of rays.

In conclusion, I wish to acknowledge my indebtedness to Prof. Sir J. J. Thomson for his kindly interest and helpful suggestions throughout the course of the investigation.

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*Fluorescent Röntgen Radiation from Elements of High Atomic Weight.*

By J. CROSBY CHAPMAN, B.Sc., Layton Research Scholar of the University of London, King's College; Research Student of Gonville and Caius College, Cambridge.

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A considerable amount of work has been done by various experimenters\* showing that, when an element of higher atomic weight than calcium is subjected to a suitable primary beam of X-rays, the rays which leave the radiator consist of two types: firstly, the purely scattered radiation, which is almost exactly similar to the incident beam, and, secondly, a characteristic homogeneous radiation. The scattered radiation which in the case of a primary beam from an X-ray bulb is heterogeneous, is, with elements of low atomic weight, quite small in intensity when compared with the intensity of the homogeneous radiation which is emitted simultaneously. Owing to this fact, it is comparatively easy to prove that the elements with atomic weights between that of calcium and cerium give off when stimulated with X-rays homogeneous beams, and the hardness of the characteristic radiation from each of these elements has been measured by determining the absorption in aluminium. The radiations are usually defined by the value of their absorption coefficients, that is, by  $\lambda/\rho$  where  $I = I_0 e^{-\lambda x}$ ;  $\rho$  = density of aluminium. Using the values obtained, it is possible to plot a curve showing the relation between atomic weight and  $\lambda/\rho$  for the elements which emit a characteristic radiation, taking atomic weight as abscissa and  $\lambda/\rho$  for ordinates. If this is done, it will be found that the elements with atomic weights between that

\* Barkla and Sadler, 'Phil. Mag.,' Oct., 1908; Chapman, 'Phil. Mag.,' April, 1911; Barkla, 'Phil. Mag.,' Aug. 1910.